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Final Report
The Clemson University
University Research Initiative Program
in Discrete Mathematics &
Computational Analysis
N00014-86-K-0693
March 1990

Clemson University created in September 1986 a University Research Initiative Program in Discrete Mathematics and Computational Analysis funded by ONR to investigate basic and applied problems in two interdisciplinary areas of the Mathematical Sciences and established an advanced computing facility to support computational research in these areas. The research focused on the areas of discrete mathematics and computational analysis. Some problems addressed have a strong potential for application into technological developments at the Navy laboratory level. Other problems address basic theoretical questions that are important to the long-term scientific interest of the Navy and support subsequent applied research of the Program. Faculty research efforts were augmented by visitors and graduate students.

A Program Steering Committee was formed to oversee the routine activities of the Program. Faculty members wishing to participate in the University Research Initiative Program were invited to submit proposals. The Steering Committee selected six projects for limited funding during the first year. These projects were continued in year two and five new projects were initiated. (Most of these new projects were initiated in the first year without funding.) In year three, support was continued to five projects. Support in all years took the form of one to three months of support, travel and colloquia from visiting mathematical scientists. Each year the Steering Committee selected outstanding visiting faculty who were supported by funds supplied by Clemson University with reduced teaching loads and who were chosen to stimulate the University Research Initiative Program. There was one visitor (Professor Kenneth Driesel) in the first year, two visitors (Professors Clark Jeffries and Peter Slater) were funded in year two and one (Professor Jennifer Key) in year three.

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The first year of the University Research Initiative Program gave special emphasis to acquiring advanced computing equipment and to establishing the new computing capability. A parallel processor machine with processors linked by a hypercube topology was purchased with funds from this contract and with other funds from Clemson University. An expanded network of terminals was provided to permit accessibility to users.

Much of the research has common mathematical threads and lends itself to interdisciplinary approaches by researchers. The interdisciplinary nature of the Program is further reflected by the computational questions that are a

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common component of each subproject. This focus on computational issues and the development of advanced computational capabilities led to the establishment of an advanced computing capability.

Specific research projects initiated in the area of discrete mathematics were:

"Combinatorial Matrix Analysis". The investigator in this project was Professor C. R. Johnson. Graduate students included in this project were Mr. Peter Nylen, Mr. Michael Lundquist. This project was somewhat curtailed when Professor Johnson relocated to William and Mary University; however the graduate students remained with the project, were directed by Professor Johnson and will have completed their Ph. D. degrees at Clemson by May 1990. Professor Jeffries (see below) also continued work in this area as part of another research project.

"Combinatorial Structures and Network Reliability" (the investigation of the rich combinatorial structure that underlies network reliability problems and the development of more efficient algorithms for calculating network reliability). The investigators on this project were Professors J. P. Jarvis and D. Shier. They were assisted by graduate research assistant Mr. Richard Lakin.

"Development of Linear Algorithms on Combinatorial Structures" (the *development of linear computation and its range of applicability to* include a wide variety of scientific algorithmic problems). The investigators on this project were Professors S. T. Hedetniemi and Renu Lasker. They were assisted by research assistants Mr. Jay Boland, Ms. Gayla Domke, Mrs. Eleanor Hare, Ms. Judy Vanderlaan, and Mr. Thomas Wimer.

"Linearization and Geometric Strategies for Special Mathematical Programming Problems" (second and third summers). The investigator on this project was Professor Warren Adams. His research assistants were Mrs. Julie Lassiter and Mrs. Terri Johnson. Professor P. M. Dearing (unsupported) and his graduate research assistant, Mr. Eric Bibelnieks, assisted on this project.

"Computational Problems in Graph Theory and Combinatorial Geometry" (summer two only). The investigator on this project was Professor Robert Jamison. Research assistants Mrs. Cindy Harris and Ms. Virginia Rice assisted in this area of research.

Specific research projects initiated in computational analysis were:

"Hierarchical Systems" (extention of current work concerning analytic properties of hierarchical matrices and development of mathematical algorithms for data analysis on parallel and systolic architectures). The

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investigator on this project was Professor Daniel Warner. He was assisted by research assistants Mrs. Tracy Bibelnieks and Mr. James Zurochak.

"Distributed Control of a Multimodal System" (development of control coordination methods based on simulation of realistic examples for multimodal systems). The investigators on this project were Professors Robert Fennell, Robert Haymond, and James Reneke. They were assisted by graduate assistants Mrs. Belinda King, Mr. Michael Pisarcik and Mr. Jody Trout.

"Nonlinear Dynamical Systems" (a methodology for partial differential equations problems, a new model in fluid flows, and dynamical systems in neurel network problems). The investigators on this project was Professors James Brannan, James Reneke, and Clark Jeffries. Assisting in the work but unsupported by the program were Professors Bose and Cover. Graduate research assistents on this project were Ms. Nancy Cauthan, Ms. Karen Funk, and Mr. Micael Reitz.

"Algorithms for Parallel Processors with Vector Nodes" (partial support in years two and three). The investigators on this project were Professors Christopher Cox and Roy Pargas. Mr. James Knisely was a research assistant on this project.

"Semantics and Processor Scheduling for Parallel Processors"(support for year two only). The investigators on this project were Professors Robert Geist, Sandra Hedetniemi, and Dennis Stevenson. They were assisted by research assistants Mr. William George, Mr. Joe Hudson, and Mr. Robert Reynolds.

"Game Theory and Equilibrium Theory" The investigators on this project were Professor Michael Kostreva and William Ruckle (summer two only). Graduate research assistants on this project were Ms. Nancy Brown and Mr. Ernest Cline.

The Steering Committee consisted of two Research Area Coordinators (discrete mathematics and computational analysis), the Head and the Associate Head of the Department of Mathematical Sciences and a member to coordinate the projects conducted with the Navy Laboratories. The Committee members for most of the program were S. T. Hedetniemi, D. D. Warner, R. Ringeisen, T. G. Proctor and J. A. Reneke.

Professor William Verry was the Technical contact from September 1986 until September 1987. (He relocated at that time because a portion of his support could not be implemented.) At this time, Professor T. G. Proctor was named Technical contact. Professors Verry and Proctor attended a year one presentation in Washington in May 1987. There was an ONR site visit in April 1988 at which some progress was reported in written form. Other reports have been submitted to ONR as follows:

1. Publications/Patents/Presentations/Honors Report submitted in December 1988,
2. Publications/Patents/Presentations/Honors Report submitted in October 1989,
3. Answers to specific questions directed to the Clemson URI investigation at site review: May 1988,
4. Progress report submitted to ONR Scientific Officer (Dr. Glassman) for his year three planning sessions in late July 1988,
5. Progress report submitted to ONR Scientific Officer (Dr. McMorris) for year two planning sessions in October 1987.

The Program scope was adjusted several times during the duration of the contract. The originally approved budget was reduced by 10% one month after the program was initiated, the second year budget was also reduced by 10% and in the third year, the Program was given only 34% of the originally approved funds and was terminated at the end of three years. Budget and expenditure summaries are attached to this report.

Funding cuts necessitated removing several aspects of the original proposal. Specifically no Advisory Committee was formed, a proposed technician was not employed, and the amount of equipment purchased was reduced. Every effort was made to deliver the proposed research objectives.

The Department of Mathematical Sciences at Clemson University is well suited to the objectives of the University Research Initiative Program. The Department has an established history and a national reputation of interdisciplinary research and teaching. The heart of the ONR University Research Initiative Program in Mathematical Sciences effort was the experience of the Research Coordinators and the principal invesigators. Their combined experience represents over $4 million in research funding from government agencies and over forty years research experience.

Graduate students, Navy Research Fellows, and postdoctoral fellows played an important role in the research tasks proposed in the Program. There was one doctoral fellow (Mr. Thomas Wimer) in the first year, two doctoral fellows (Mr. Peter Nylen and Mr. Eric Bibelnieks) for year two and one (Mr. Eric Bibelnieks) in year three. There were four graduate research assistants in the first year, seventeen students received research support in year two and eight will receive support in year three. Navy Research Fellows were advanced graduate students who had been admitted to candidacy and whose dissertation topics were relevant to research supported by the University Research Initiative Program. The ONR University Reserach Initiative Program has definitely enhanced Clemson University's reputation for graduates in the applied mathematical sciences.

The ONR University Research Initiative Program organized and partially supported four two-day mini-Conferences on Discrete Mathematics. These mini-conferences are held in October each year and consist of twelve thirty

minute talks by invited speakers and workshop sessions at night and between sessions. Attendance at these conferences has risen from about thirty visitors from largely regional institutions to sixty visiting distinguished scientists from all regions of the United States and Canada. This has been one of the highlights of the URI program at Clemson. Programs for the four URI sponsored mini-conferences are part of this document. Announcements for the fifth mini-conference has been mailed.

The URI Program also held a two day Workshop on Parallel Computing in November 1987 with twelve speakers and forty eight participants. Other Program activity at Clemson included three short courses on the T-20 hypercube for Clemson faculty and graduate students, seminars in specific research areas (graph theory, applied analysis, and parallel algorithms) which were maintained throughout the contract, and a limited colloquia series with invited speakers from other institutions as follows (listed in order of the visit to Clemson):

Thomas J Morin	Purdue University
Barry Peyton	Boeing Computer Services
Guillermo Owen	Naval Postgraduate School
Arthur Hobbs	Texas A&M University
Edward Assmus	Lehigh University
Ernst Stephan	Georgia Institute of Technology
Pauline van den Drissche	University of Victoria
Gary Hewer	Naval Systems Weapons Center
Pitu Michandani	Rennslear Polytechnic Institute
Volker Wikstutz	UNC Charlotte
Pierre Hansen	RUTCOR
David Fielding	Cornell University
John Burns	Virginia Polytechnic Institute
John Baxley	Wake Forest University
Tsu-Fen Chen	University of Texas in Arlington
Fumio Kojima	ICASE
Joseph Ecker	Rennslaer Polytechnic Institute
Gerde Fricke	Wright State University

Contacts were made at five Navy Installations: the Naval Coastal Systems Center, the Naval Ocean Systems Center, the Naval Research Laboratory, the Naval Systems Weapons Center, the Naval Underwater Systems Center, and the Naval Personnel Research and Development Center. Visits were made to each of these laboratories. A presentation was made at a joint National Science/Naval Research Laboratory (Washington, D. C.) a Clemson University faculty member spent a year at the Naval Postgraduate School, and another faculty member spent a summer at the Naval Underwater Systems Center. Three research proposals were formulated by Clemson faculty with specific personnel at Navy laboratories. At this time, one of these is pending, one is being reworked and the third is dormant.

Work Accomplished in Discrete Mathematics. A research focus in linear algorithms for a new class of graphs formed at the beginning of the contract and maintained a vigorous life throughout the period. The core group included leaders Professors Steven T. Hedetniemi and Renu Laskar, their students, and some additional faculty members. Faculty from other institutions regularly visited the weekly meetings. This group developed a methodology and supporting theory for constructing new linear time algorithms for solving NP-complete problems when restricted to certain families of graphs, called k-terminal graphs (or equivalently graphs of bounded tree-width, or partial k-trees). To date, it is known this methodology can be used to construct new linear time algorithms for solving more than 50 types of problems on any of 30 families of graphs. In the course of this research, approximately one dozen new algorithms were actually constructed and written up for publication. Approximately one dozen presentations were also made of this methodology at various international and national conferences and colloquia.

Key ingredients in this research were the Ph. D. theses written by Thomas V. Wimer, Eleanor Hare and Chandrasekharan Narayanan (in chronological order). The first of these was entitled "Linear Algorithms on k-Terminal Graphs and developed the basic methodology and theory. Dr. Hare's work concerned the solution of various NP-complete problems on grid graphs (m by n checkerboards) and the last of these works explored extensions of Wimer's work to enumerating the totality of solutions to a given problem on a graph and producing logarithmic time, parallel versions of these linear time sequential algorithms.

In an effort to study the theoretical limitations of Wimer's methodology, a new class of combinatorial optimization problems was discovered for which the methodology fails. These are problems involving real valued functions on the vertices of a graph which satisfy certain independence, domination or irredundance conditions. The problem in general is to find such a function on a given graph which has either a minimum or a maximum total value. This area of computational study is called fractional graph theory. A number of theoretical and computational advances into problems of this type were made by Professors Hedetniemi, Laskar Hare and Jacobs (Clemson) along with Professor Gerd Fricke (Wright State) and Grant Cheston (University of Saskatchewan). Also a fourth thesis was written by Dr. Gayla Domke which explores some of the theoretical properties of these newly defined fractional parameters of graphs.

There were twenty-one publications from the group mentioned above in three years. There were ten publications resulting from the work of Professor Key in the area of block designs and coding. Professor Jamison's work in references 25 and 26 nicely complemented Key's work. Professor Jarvis and Shier continue to collaborate having produced four papers on this project in the area of network reliability. Finally Professor Adams work in the combinatorial area of a mathematical programming complemented both the

graph theory group effort and the computational analysis work by Professor Warner.

Work Accomplished in Computational Analysis. The following is a brief summary of the work accomplished in the area of computational analysis. References are given to the publications and technical reports generated by the faculty on this contract.

Reneke, Fennell, Brannan and Bose applied reproducing kernel Hilbert (RKH) space methods to several problems arising in the theory of linear deterministic and stochastic hereditary systems. This research included new controllability and filtering results, the design of feedback control, and simulation. The finite dimensional approximations that flow from these representations led to numerical implementations in control and simulation. A series of examples and the associated computational results and graph were developed throughout the contract. This work is contained in references 46, 51, 52, 53, 91. A separate work in stochastic differential equations in reference 4.

Bose, Cover and Reneke developed sufficient conditions for two and three dimensional quadratic nonlinear ordinary differential equations to be point dissapative, a weaker type of global asymptotic behavior than limit point/limit set. These results are simple to state but surprisingly difficult to establish. This work is contained in references 44, 45. Another nonlinear control problem result is 54.

An eigenspace assignment approach to the design of parameter insensitive control laws for linear multivariable systems has been developed. It utilizes constrained optimization techniques and felxibility in eigenvector assignments to reduce control sensitivity to parameter changes. Robustness and performance is maintained. The method is computationally intensive. This approach has been applied to study symmetric flutter suppression in an aeroelastic vechicle. The method provides feedbck control laws making closed loop stability less sensitive to changes in dynamic pressure. This work is contained in references 39, 40, 41.

Professor Clark Jeffries was invited to visit Clemson during the second year of the contract as a stimulus to the URI Program. He later was employed by Clemson University as a regular faculty member. His work in dynamical systems fall roughly into four categories: neurel networks (see references 64, 65, 66, 71, 72, 73), a new model in fluid dynamics (see reference 67), a new formulation of the electromagnetic equations (see references 69, 75) and qualitative stability (see references (43, 68, 70, 74). The electromagnetics research has led to a new conservation for classical radiation, resolution of the self-force problem and a new account of radiation from an accelerating particle, replacing Larmor's formula. The neurel network research has investigated models which use multinomials as opposed to the familar Hopfield model which is linear in gain function. Applications have focused on correction of binary code. Finally, the research on qualitative stability has

continued Professor's Jeffries work on the sign structure in terms of linear and nonlinear systems. This particular effort complemented Professor Johnson's interrupted project on matrix analysis (see also references 76, 77, 78). The research in fluid dynamics has developed the consequences of a novel term in the energy equation, called pressure diffusion. Models incorporating this term offer new accounts for three phenomena: increase of sound speed with frequency in gases, density ripples ahead of bow shocks and condensation in shocks in air. Another result in the area of fluid dynamics (accoustical trajectories) was obtained by Professor Brannan (reference 47).

Professors Warner, Haymond, Reneke, and Cox conducted research using the hypercube computer assisted by their students. The primary work coming out of this effort concerned computational results in robot arms (see references 60, 61, 62) and computation algorithms using parallel coprocessors for tridaiagonal matrices (see references 48 and 50). See also the project by Reneke and his research assistant (Trout) concerning image processing on the hypercube, reference 90. Finally Professor Cox was a collaborator in the work reported in reference 49. Professor Warner's work, reported in 103, is connected with the solution of sparse systems arising in partial differential equations.

Professors Stevenson and Geist's work on parallel computers is reported in references 55 - 59 and 98 - 102. Related work conducted by another URI investigator is reported in references 88 and 89.

Finally Professors Kostreva and Ruckle were partially supported for one summer for an investigation in game and equilibrium theory research related to distributed systems. Their work during that summer led to a number of results (see references 79 - 87 and 92 - 97). Joint activity with others researchers in distributed systems and with a computng environment suitable for this activity was not available during that time and it remains unclear how distributed systems may be used in this area; however the period was very productive and these individuals began or worked on a number of projects in the area.

Index of Publications
Discrete Mathematics

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2. Allan, R., Domke, G. S., Hedetniemi, S. T., and Renu Laskar, "Generalized packings and coverings of graphs", Congressus Numerantium 62 (1988) 259-270.

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78. Johnson, C. R., an d L. Rodman, "Completion of Toeplitz partial contractions to contractions", to appear in the SIAM Journal on Algebraic and Discrete Mathematics.

79. Kostreva, M. M., K. R. Pattipati, and J. L. Teele, "Approximate mean value analysis algorithms for queueing networks: new formulations and convergence results", to appear in Journal of the Assoc. for Computing Machinery.

80. Kostreva, M. M., "Nonconvexity in noncooperative game theory", International Journal of Game Theory, 20 (1989) 247-259.

81. Kostreva, M. M., (with L. Kinard) "A differentiable homotopy approach for solving polynomial optimization problems and noncooperative games", to appear in Computers and Mathematics with Applicationst.

82. Kostreva, M. M., "Recent results on complementarity models for engineering and economics", to appear in INFOR (Journal of the Canadian Operations Research Society).

83. Kostreva, M. M., "A large scale zero-one programming model for achievement of corporate average fuel economy (CAFE) standards at minimum cost", submitted to Operations Research.

84. Kostreva, M. M., "Combinatorial optimization in Nash games", submitted to Discrete Applied Mathematics.

85. Kostreva, M. M., "Computational experience with homotopy continuation for polynomial models in optimization and noncooperative game theory", Lecture Notes for 1988 AMS-SIAM Summer Seminar, Colorado State University, Fort Collins, CO, L35-MMK-1-31.

86. Kostreva, M. M., "Tools for validation and analysis of fire models", J. P. Jarvis and L. J. Forney, Proceedings of 1987 Fall Technical Meeting, Combustion Institute/National Bureau of Standards, Gaithersburg, MD.

87. Kostreva, M. M., K. R. Pattipati and J. L. Teele, "On the properties of approximate mean value analysis algorithms for queueing networks", ACM Performance Evaluation Review 16 (1988) 244-252.

88. Pargas, R., and T. Murray, "Tridiagonal linear system solvers on hypercube multicomputers," Proceedings of the Fourth Conference on Hypercube Concurrent Computers and Applications, Monterey, 1989.

89. Pargas, R., Peck, J., and A. Pugh, "Use of a semijoin program for join queries on a hypercube," Proceedings of the Fourth Conference on Hypercube Concurrent Computers and Applications, Monterey, 1989.

90. Reneke, J. A., "Implementation of a morphological image processing algorithm on an FPS T20 hypercube", (with J. D. Trout, Jr.), Proc. 20th South. Symp. on System Theory, Charlotte, NC, March, 1988, 312-316.

91. Reneke, J. A., and A. Bose, "Conditions yielding weak controllability for linear hereditary systems", to appear in Proceedings of Ninth International Conference in Analysis and Optimization of Systems, Antibes.

92. Ruckle, W. H., "Local theories of the linearizing projection", submitted to the International Journal of Game Theory.

93. Ruckle, W. H., "The gold-mine game", (with V. Baston and J. Bastockel) submitted to the Journal of Optimization Theory and Applications.

94. Ruckle, W. H., "A discrete search game", submitted to Journal Indian Mathematical Society.

95. Ruckle, W. H., "On the symmetry axiom for values of nonatomic games", (with D. Monderer) submitted to the International Journal of Mathematics and Mathematical Sciences.

96. Ruckle, W. H., "The linearizing projection, global theories", International Journal of Game Theory 17 (1988) 67-87.

97. Ruckle, W. H., "The strong topology on the dual space of a summability field and the mu-continuity problem", (with J. C. Mayer) Math. Zeitschrifte 195 (1988) 409-413.

98. Stevenson, D. E., "A vector C and Fortran compiler for the FPS T-series", to appear in Software: Practice and Experience.

99. Stevenson, D. E., "Experiences in language development for distributed computing", Proceedings of the Conference on Hypercube Concurrent Computers and Appliocations, 1989.

100. Stevenson, D. E., "A parallel implementation of Neville's algorithm", Computational Atomic and Nuclear Physics at One Gigaflop, Nuclear Science Research Conference Series, volume 16, C. Botteher, M. R. Strazer and J. B. McCory, editors, New York: Haymond Academic Publishing Company, 1989, 221-228.

101. Stevenson, D. E., "A canonical form for parallel programs", Proceedings of the Conference on Hypercube Concurrent Computers and Appliocations, 1988, 536-540.

102. Stevenson, D. E., "Experiences in language development for distributed computing", Proceedings of the Conference on Hypercube Concurrent Computers and Appliocations, 1989.

103. Warner, D. D., Dearing, P. M. and D. R. Shier, "Maximal chordal subgraphs", Discrete Applied Mathematics, 20 (1988) 181-190.

Presentations at Professional Meetings
ONR University Research Initiative Program

1. American Mathematical Society Meeting in Liousville, January, 1990.
   Reneke, J. and A. Bose, "Existence of a linear feedback control for certain types of global stability" and R. E. Fennell, J. A. Reneke, "Application of RKH space methods to the design of robust controls for linear stochastic hereditary systems".
2. SIAM Parallel Processing Conference in Chicago, December 1989. Cox, Christopher, " Performance of Two Algorithms on a parallel Processor with Vector Nodes" and Sun, Hung, "Parallel homotopy algorithm for symmetric tridiagonal eigenvalue problem" and Dennis Stevenson, "Distributed Kernel for Logic Processing"
3. IEEE Conference on Decision and Control in Tampa, December 1989.
   R. E. Fennell and J. A. Reneke, "Application of RKH space methods to thedesign of robust controls for linear stochastic hereditary systems".
4. ORSA/TIMS Conference in New York, October 1989.
   W. Adams, "A hierarchy of relaxations and convex hull characterizations for linear and polynomial mixed-integer zero-one programming problems",
   W. Adams and J. Lassiter, Constructing upper approximations of pseudo-boolean functions".
5. Southeastern Conference on Differential Equations in Charlotte, October 1989.
   J. A. Reneke and R. E. Fennell, "Applications of RKH space methods to the design of robust controls for linear hereditary systems".
6. Workshop: Graphs with Bounded Tree Width in Eugene, Oregon, August 1989.
   S. T. Hedetniemi and C. Narayanan, "Fast parallel algorithms and enumeration techniques for partial k-trees".
7. International Conference on Blocking Sets in Griessen, FDR, July 1989.
   R. Jamison, "Helly type covering theorems".
8. Workshop on Matroids and their Relatives in Bielefeld, FDR in June 1989.
   R. Jamison, "Compatible orders on biconvex geometries".
9. American Mathematical Society Meeting in Chicago, June 1989.
   W. R. Ruckle, "local theories of the lineariziinf projection".
10. International Conference on Neurel Networks in Washington, D. C., June 1989.
    Clark Jeffries, "Hypergraph analysis of neurel networks".
11. SIAM Meeting in San Diego, June 1989.
    Warner, D. D, "Structural Properties of Hierarchical Matrices".
12. The ARIDAM Conference at Rutgers, June 1989.
    W. Adams, "A Hierarchy of Relaxations between the Continuous and Convex Hull Representations for Zero-One Programming Problems." This talk was also presented at the May ORSA/TIMS meeting in Vancoeuver in May.
13. American Mathematical Society Meeting at Loyola University, May 1989
    Key, J., "Codes and Designs".
14. The SIAM Conference on Control in 90's in San Francisco, May 1989. R. E. Fennell and J. A. Reneke, "Simulation of Stochastic Linear Systems".
15. Pittsburgh Simulation Conference, Pittsburgh, May 1989.
    Thornton, J., "Discrete-continuous hybrid simulation using standard ODE integrators", Thornton, J. and R. Haymond, "Event detection methopds in discrete-continuous hybrid simulation of a robot arm".
16. SIAM Conf on Optimization in Boston, April 1989.

Kostreva, M., "Nonconvexity in noncooperative game theory".

17. SIAM Conf Sparse Matrices in Salishan, Oregon, April 1989.
    Warner, D., "Chordal graphs and hierarchical matrices".
18. SE Systems Theory Symposium in Tallshassee, April 1989.
    Reneke, J. and A. Bose, "Linear feedback control for a class of nonlinear systems
19. Fourth Hypercube Conference in Monterey, March, 1989.
    Cox, C., "Solving banded linear systems on a hypercube with vector nodes",
    Stevenson, D., Experiences in language development for distributed computing".
20. IMACS Symposium in Princeton, March 1989.
    Cox, Christopher and J. A. /Brannan, "Application of the boundary integral element method in numerical ocean acoustics".
21. Domain Decomp Conference in Houston, March 1989.
    Warner, D., "Solving structural problems using the FPS T-20".
22. Second Auburn Conference on Design Theory, March 1989.
    Key, J., "Codes and Designs".
23. 20th SE International Conferenceon Combinatorics in Bocca Raton, February 1989. Laskar, R. "Simplicial graphs".
24. ORSA Computer Sc ienceTechnical Section in Williamsburg, January 1989.
    Jarvis, J. P., D. Shier and A. Perticone, "Evaluation and design of a voice telecommunication network".
25. SE Conference on DE in Athens, November 1988.
    Fennell, R. E. and J. A. Reneke, "Simulation of Linear Stochastic Systems". This talk was also given at the Midwest Conference on DE in Ames, November 1988.
26. Carbondale Combinatorial Conference, October 1988.
    Laskar, R. "Inequalities involving the rank of a graph".
27. ORSA/TIMS Conference in Denver, October 1988.
    Johnson, C., Dearing, P. M., Adams, W. "On the equivalance between root duality and Lagrangian duality for unconstrained 0-1 quadratic programming problems".
28. IEEE Conference on Intelligent Control in Arlington, September 1988.
    Jeffries, C. "Mathematical analysis of neurel networks used in the solution of set selection problems".
29. Conference on Numerical Solutions of Partial Differential Equations, Blacksburg, September 1988. Cox, C., "On least squares approximations to first order elliptic systems in three dimensions".
30. 26th Allerton Conference Communications, Control & Computing in Urbana, September 1988. Naraynan, C. and S. Hedetniemi, "Fast parallel algorithms for tree decomposing and parsing partial k-trees".
31. IMA Conference in England, August 1988. Johnson, C. R., "Applications of matrix theory".
32. IMAC/SIAM Conference on Signal Processing in Minneapolis, August 1988.
    Brannan, J., "Some signal processing problems in underwater acoustics".
33. AIAA Conference in Minneapolis, August 1988. Fennell, R., "An application of eigenspace method to symmetric flutter suppression"
34. SIAM Discrete Mathematics Conference in SanFrancisco, July 1988.
    Hedetniemi, S. T. and D. P. Jacobs, "The computation of fractional dominating functions of graphs".
35. Kalamazoo Graph Theory Conference, July 1988. Hedetniemi, S., R. Laskar and G. Domke, "Fractional dominating functions of graphs".
36. Johns Hopkins Matrix Theory Conference, July 1988.

Moss, W., "Backward error analysis for a pole assignment problem".

37. Coalitional Stability Workshop in Columbus, July 1988.
Ruckle, W., "A discrete search game".
38. 3rd Supercomputing Conference in Boston, June 1988.
Stevenson, D., "A vector C and Fortran compiler for the FPS T-series".
39. 8th International Conference Analysis & Optimiztion, INRIA at Antibes, June 1988. Reneke, J. "Conditions yielding weak controllability for linear hereditary systems".
40. Pittsburgh Simulation Confence, May 1988.
Haymond, R., Thornton, J. , Fennell, R., "RKH Space simulation of stochastic linear hereditary systems".
41. ORSA/TIMS Conference in Washington, May 1988.
Jarvis, J. P., and D. R. Shier, "Approximate analysis of networks with multiumodal components", Kostreva, M., "Solving polynomial optimization problems and non-cooperative games by a homotopy algorithm", "Nonconvexity in Nash equilibrium theory", "Approximate mean value analysis algorithms for queueing networks: new formulations and convergence results"..
42. SIAM Conference on Linear Algebra in Madison, May 1988.
Moss, W. and C. Cox, "Sensitivity analysis for the single input pole assignment algorithm", Kostreva, M., "P-functions in applied mathematics".
43. SE Systems Theory Symposium in Charlotte, March 1988.
Jeffries and Trout, J., "Vectorization of morphological image processing algortihms".
44. SE Section SIAM Meeting, Tennessee Space Institute, March 1988.
Fennell, R. E., "Eigenspace methods for the design of parameter insensitive control laws".
45. Nineteenth SE International Conference on Combinatorics in Baton Rouge, February, 1988. Hedetniemi, S., R. Laskar and G. Domke, "Fractional packings, coverings, and irredundance in graphs".
46. Third Hypercube Conference at Pasadena, January 1988.
Cox, C., "A cyclic reduction algorithm for a parallel processor with vector nodes", Stevenson, D., (need title here)
47. American Mathematical Society Meeting, January 1988.
Reneke, J. and A. Bose, "An RKH-space characterization of weak controlability for a class of linear heredtary systems".
48. SEAS Section Meeting of SIAM in Athens, March 1987.
Reneke, J. and A. Bose, "Conditions yielding weak controllability for a class of linear hereditary systems", D. Warner and J. Thornton, "A shortest path algorithm and its implementation on the FPS T-20 hypercube".
49. Control 87 International Symposium on Intelligent Control in Washington, January 1987. Fennell, R., "Canonidcal forms for distributed systems".

3/28/90

The Clemson University Research Initiative Program in Discrete Mathematics and Computational Analysis

Index of Technical Reports

URI-001
Stephen T. Hedetniemi and R. Laskar, "A Linear Algorithm for Finding a Minimum Dominating Set in a Cactus," Discrete Appl. Math., 13, (1986), 287-292, (with J. Pfaff)

URI-002
Stephen T. Hedetniemi and R. Laskar, "On Irredundance, Dimension and Rank of Posets," to appear Proc. First China-U.S.A. Internat. Conf. on Graph Theory and its Applications , (Jinan, China, 1986)

URI-003
Stephen T. Hedetniemi and R. Laskar, "On the Equality of the Grundy and Ochromatic Numbers of a Graph," J. Graph Theory. 11, #2 (1987), 1157-159, (with W. R. Hare and P. Erdos)

URI-004
Stephen T. Hedetniemi, R. Laskar, and T. Wimer, "Linear Time Computability of Combinatorial Problems on Generalized Series-Parallel Graphs, Discrete Algorithms and Complexity Theory," Proc. Japan-U.S. Joint Seminar, June 4-6, 1986, Kyoto, Japan, D. Johnson, T. Nishizeki, A. Nozaki and H. Wilf, Eds., Perspectives in Computing. Vol. 15, Academic Press, 1987, 437-457, (with E. O. Hare and K. Peters)

URI-005
Stephen T. Hedetniemi and R. Laskar, "A Bipartite Theory of Graphs: I," Congr. Numer. , 55, (1986), 5-14

URI-006
Stephen T. Hedetniemi and R. Laskar, "A Bipartite Theory of Graphs: II," to appear Utilitas Mathematica, Proc. 250th Anniversary Conf. on Graph Theory, (Ft. Wayne, Ind., 1986)

URI-007
Stephen T. Hedetniemi and R. Laskar, "Recent Results and Open Problems in Domination Theory," to appear SIAM J. Alg. Disc. Meth.

URI-008
Stephen T. Hedetniemi, R. Laskar and T. Wimer, "On Maximal/Minimal Connectivity in Graphs," ARS Combinatoria, 21, (1986), 59-70, (with K. Peters)

3/28/90

URI-009

Stephen T. Hedetniemi and R. Laskar, "On The Strength of a Graph," Congr. Numer. 53, (1986), 247-262, (with K. Peters)

URI-010

Stephen T. Hedetniemi and R. Laskar, "The Partite-Chromatic Number of a Graph," Congr. Numer. , 53, (1986) 235-246, (with G. S. Domke and K. Peters)

URI-011

Stephen T. Hedetniemi and T. Wimer, "K-Terminal Recursive Families of Graphs," to appear Utilitas Mathematica, Proc. 250th Anniversary Conf. on Graph Theory, (Ft. Wayne, Ind., 1986)

URI-012

Stephen T. Hedetniemi and R. Laskar, "Gallai Theorems for Graphs, Hypergraphs and Set Systems," to appear Proc. First Japan Conf. on Graph Theory and Applications, (Hakone, Japan, 1986), (with E. J. Cockayne)

URI-013

Stephen T. Hedetniemi , "A Survey of Gossiping and Broadcasting in Communication Networks," to appear Networks, (with S. M. Hedetniemi and A. Liestman)

URI-014

Stephen T. Hedetniemi and T. V. Wimer, "Linear Time Resource Algorithms for Trees," (with S. M. Hedetniemi)

URI-015

Stephen T. Hedetniemi, "On the Diagonal Queens Domination Problem," J. Combinatorial Theory, 42, (1986), 137-139, (with E. J. Cockayne)

URI-016

Stephen T. Hedetniemi, "Algorithms for Computing the Domination Number of KxN Complete Grid Graphs," Congr. Numer., 55, (1986) 81-92, (with E. O. Hare and W. R. Hare)

URI-017

Stephen T. Hedetniemi and R. Laskar, "Generalized Packing and Coverings of Graphs," submitted to Congr. Numer., 62, (1988), 259-270, (with B. Allan and G. Domke)

URI-018

Daniel D. Warner, J. Thornton and R. Haymond, "A Shortest Path Algorithm in Robotics and its Implementation of the FPS-20 Hypercube," (presented at the March 1987 SIAM-SEAS meeting in Athens, Georgia) , submitted for publication.

3/28/90

URI-019

Walter G. Bullard, Jr., "Analysis and Vectorization of A Molecular Dynamics Model", (a paper submitted to the Dept. of Math. Sciences in partial fulfillment of the requirements for the degree of Master of Science, Mathematical Sciences, August 1987). Dr. Daniel D. Warner, Major Advisor.

URI-020

Charles R. Johnson "A Gersgorin-type Lower Bound for the Smallest Singular Value," submitted for publication.

URI-021

Charles R. Johnson, "Evaluation Techniques for Paired Ratio Comparison Matrices in a Hierarchical Decision Model," accepted for publication in Measurements in Economics, Physica-Verlag, Heidelberg 1987, (with J. M. Hiln).

URI-022

Renu Laskar, "Chromatic Polynomials of Chordal Graphs, Congr. Numer., 61 (1988), 133-142, (with N. Chandrasekharan and C. E. Veni Madhavan))

URI-023

James R. Brannan , "Parabolic Ray Theory with Boundaries," (presented in preliminary form at the Southeastern Atlantic Conference of Differential Equations, October 1987 in Clemson).

URI-024

James A. Reneke and R. E. Fennell, "Canonical Forms for Distributed Systems Control," Proceedings of the 1987 IEEE International Symposium on Intelligent Control. (This paper is contained in URI-040).

URI-025

Charles R. Johnson, "Aggregation of Markov Processes: Axiomatization," submitted for publication, (with E. Howe).

URI-026

Charles R. Johnson, "Inequalities Relating Unitarily Invariant Norms and the Numerical Radius," to appear in Linear and Multilinear Algebra, (with Chi-Kwong Li)

URI-027

Charles R. Johnson, "The Perron Root of a Weighted Geometric Mean of Nonnegative Matrices," submitted for publication, (with L. Elsner and J. A. Dias da Silva)

URI-028

Renu Laskar, "Maximal Clique Separators of Chordal Graphs," submitted to Congr. Numer., (with J. Chandrasekharan and S. Iyengar)

3/28/90

URI-029
Renu Laskar, "The Edge Achromatic Number of Small Complete Graphs, " submitted to Congr. Numer., (with R. Rowley, R. Jamison and C. Turner)

URI-030
Thomas Wimer, "Linear Algorithms on k-Terminal Graphs," A dissertation presented to Graduate School of Clemson University.

URI-031
D. R. Shier, "Generating the States of a Probabilistic System," submitted for publication , (with E. J. Valvo and R. E. Jamison)

URI-032
D. R. Shier, "The Monotonicity of Power Means Using Entropy," submitted for publication.

URI-033
Clark Jeffries, "Fluid Dynamics with Pressure Diffusion," submitted for publication. (Summary submitted to "Applied Mathematics Letters.")

URI-034
D. R. Shier, "Adaptive Methods for Graphing Functions", (with G. A. Vignaux).

URI-035
Peter J. Slater, "A Summary of Results on Pair-Connected Reliability".

URI-036
Clark Jeffries, "Traveling Waves and Shocks With Pressure Diffusion" to appear Applied Mathematics Letters.

URI-037
Christopher L. Cox, "Implementation of a Divide and Conquer Cyclic Reduction Algorithm on the FPS T-20 Hypercube".

URI-038
Robert E. Fennell, "An Application of Eigenspace Methods to Symmetric Flutter Suppression" submitted to Proceedings- AIAA Guidance, Navigation and Control Conference. (Also appears as NASA Contractor Report ICASE Report No. 88-90.)

URI-039
James A. Reneke and James R. Brannan, "Application of RKH Space Methods to the Filtering Problem for Linear Hereditary Systems."

URI-040
James A. Reneke and R. E. Fennell, "Canonical Forms for Distributed Systems Control II".

3/28/90

URI-041

James A. Reneke and R. E. Fennell, "Convergence of RKH Space Simulations of Stochastic Linear Hereditary Systems".

URI-042

Robert E. Fennell, R. E. Haymond, and James A. Reneke, "RKH Space Simulations of Stochastic Linear Hereditary Systems".

URI-043

Charles R. Johnson, "The Potentially Stable Tree Sign Patterns for Dimensions Less than Five", submitted to SIAM Journal of Matrix Analysis and Applications (with Tracy A. Summers).

URI-044

Michael E. Lundquist, "An Implementation of the Preconditioned Conjugate Gradient Algorithm on the FPS T-20 Hypercube", paper submitted to the Dept. of Math. Sci. of Clemson Univ. in partial fulfillment of the requirements for the degree of Master of Science, Mathematical Sciences, December 1987, Daniel D. Warner, Major Advisor.

URI-045

S. T. Hedetniemi and R. Laskar, "Efficient Domination in Graphs", submitted for publication (with E. J. Cockayne and B. L. Hartnell).

URI-046

S. T. Hedetniemi, "The Subchromatic Number of a Graph", Discrete Math., 74 (1989), to appear, (with M. O. Albertson, R. E. Jamison and S. C. Locke).

URI-047

Kenneth R. Driessel, "On Isospectral Surfaces in the Space of Symmetric Tridiagonal Matrices".

URI-048

Peter J. Slater, "On Minimum Dominating Sets with Minimum Intersection", (with Dana L. Grinstead).

URI-049

William H. Ruckle, "Abstract of the Linearizing Projection, Local Theories".

URI-050

William H. Ruckle, "On Win-Lose-Draw Games".

URI-051

William H. Ruckle, "Computer Studies of Coalition Formation Under Varying Dynamics".

3/28/90

URI-052

Richard J. Lakin, "State Space Approximation of a Multimode-Component System",

URI-053

E. O. Hare, S. T. Hedetniemi and R. C. Laskar, "Simplicial Graphs", submitted to Congr. Numer., (with Grant A. Cheston).

URI-054

Gayla S. Domke, S. T. Hedetniemi and R. C. Laskar, "Fractional Packings, Coverings, and Irredundance in Graphs", submitted to Congr. Numer.

URI-055

Michael M. Kostreva, "Recent Results on Complimentarity Models for Engineering and Economics".

URI-056

Stephen T. Hedetniemi, "Spanning Trees With Specified Centers in Biconnected Graphs", (with Grant A. Cheston, Art Farley and Andrzej Proskurowski), submitted.

URI-057

John D. Trout, Jr., "Vectorization of Morphological Image Processing Algorithms", paper submitted to the Dept. of Math. Sci. of Clemson Univ. in partial fulfillment of the requirements for the degree of Master of Science, Mathematical Sciences, James A. Reneke, Major Advisor.

URI-058

J. P. Jarvis, "Discrete Structures and Reliability Computations", to appear Proceedings Interface '88, (with D. E. Whited and D. R. Shier).

URI-059

Christopher L. Cox, "On Least Squares Approximations to First Order Elliptic Systems in Three-Dimensions".

URI-060

Gayla S. Domke, Stephen T. Hedetniemi and Renu C. Laskar, "Relationships Between Integer and Fractional Parameters of Graphs", (with G. Fricke).

URI-061

Warren P. Adams, "On the Equivalence Between Roof Duality and Lagrangian Duality for Unconstrained 0-1 Quadratic Programming Problems", (with P. M. Dearing).

URI-062

James A. Reneke, "Stochastic Differential Equations in Mathematical Demography: A Review", to appear in Special Issue of "Applied Mathematics and Computation" devoted to SCE's in different fields, (with Marc Artzrouni).

3/28/90

URI-063
S. T. Hedetniemi and N. Chandrasekharan, "Fast Parallel Algorithms for Tree Decomposing and Parsing Partial k-Trees".

URI-064
Belinda B. King, "The Dynamics of the Motion of a Filament: A Survey of the Literature".

URI-065
William H. Ruckle, "A Discrete Game of Infiltration".

URI-066
Robert Geist and Sandra Hedetniemi, "Disk Scheduling Analysis via Random Walks on Spiders".

URI-067
Stephen T. Hedetniemi, "On the Computational Complexity of Upper Fractional Domination", (with G. Cheston, G. Fricke and D. J. Pokrass).

URI-068
Stephen T. Hedetniemi and Renu Laskar, "Inequalities Involving the Rank of a Graph", (with D. P. Jacobs).

URI-069
Gayla S. Domke, "Variations of Colorings, Coverings, and Packings of Graphs", Dissertation Presented to the Graduate School of Clemson University in Partial Fulfillment of the Requirements for the Degree Doctor of Philosophy, Mathematical Sciences, August 1988.

URI-070
Daniel D. Warner, "The Design of High-Performance Algorithms for the NAS AS/LX-V60", (with Wayne H. Dyck and Keith H. Thoms).

UIR-071
Chandrasekharan Narayanan, "Fast Parallel Algorithms and Enumeration Techniques for Partial k-Trees," Dissertation Presented to the Graduate School of Clemson Univ. in partial fulfillment of the requirements for the Degree Doctor of Philosophy, Math. Sciences, August, 1989.

URI-072
J. Lalani, R. Laskar, and S. T. Hedetniemi, "Graphs and Posets: Some Common Parameters."

URI-073
R. Laskar and A. Majumdar, "A Fractional View of Graph Theory", (with G. Fricke).

3/28/90

URI-074
J. Boland, R. Laskar and C. Turner, "On Mod Sum Graphs", (with G. Domke).

URI-075
R. Laskar and S. Stueckle, "On the Edge-Integrity of Some Graphs and Their Complements", (with B. Piazza).

URI-076
Christopher L. Cox and James K. Knisely, "A Tridiagonal System Solver for Distributed Memory Parallel Processors with Vector Nodes" submitted to the Journal of Parallel and Distributed Computing.

URI-077
J. A. Reneke and A. K. Bose, "Conditions Yielding Weak Controllability for a Class of Linear Hereditary Systems", submitted to the Proceedings of the Nineth International Conference Analysis Optimization of Systems in Antibes, France.

URI-078
A. K. Bose, A. Cover and J. A. Reneke, "Conditions which Imply Point Dissapation in a Quadratic Nonlinear Ordinary Differential Equation".

The Clemson mini-Conference

ON[R]

Discrete Mathematics

Clemson, South Carolina
October 9-10, 1986

Schedule of talks
(All talks given in Daniel Auditorium)

Thursday, October 9th

1:00 - 1:05 Welcoming Remarks

1:05 - 1:15 Dr. F. R. McMorris, Office of Naval Research

1:15 - 1:55 Prof. David Sumner, Department of Mathematics, University of South Carolina

"Forbidden Induced Subtrees"

In this talk we will discuss the effects of forbidding particular trees as induced subgraphs of a graph. It is surprising just how much a restriction affects the properties of a graph. We will discuss tie-ins with the domination number, Hamiltonicity, 1-factors, toughness, and particularly the chromatic number.

2:15 - 2:55 Prof. Narsingh Deo, Department of Computer Science, University of Central Florida

"Approximation Algorithms for the Gate Matrix Layout Problem"

Lopez and Law in 1980 proposed a dense style of CMOS circuit layout, called the gate matrix. The problem of minimizing the number of tracks (and hence the silicon area) for a given set of gates and their interconnection was shown to be NP-complete by Wing in 1982. An attractive dynamic-programming formulation as well as a number of special-case optimization algorithms were given by Deo, Krishnamoorthy and Langston in 1985. In this talk we will look at some of the approximation algorithms and their performance for the gate matrix layout problem. In particular a local-search heuristic will be examined in detail. The expected value of the silicon area will be derived analytically, assuming a uniform distribution on the input. The analytical results will be compared with extensive empirical data.

*Supported by the U.S. Army Research Office under grant DAA29-82-K0107

3:15 - 3:55 Prof. Robert W. Robinson, Chairman, Department of Computer Science, University of Georgia
(Joint with R. C. Reed)

"Enumeration of Labeled Diagraphs with Given Degrees"

The superposition method for counting labeled pseudo diagraphs is introduced. This method allows direct computation of the exact number of such diagraph with given in- and out-degrees. The corresponding numbers of labeled diagraphs can then be enumerated by inclusion-exclusion, as reported by Katz and Powell in 1954. Numerical results for labeled 2- and 3-regular diagraphs were calculated in the manner for up to 14 nodes.

Also discussed are recurrence relations obtained by repeated reduction for the numbers of labeled 2-regular and regularly oriented 4-regular graphs. Numerical results were determined using these recurrences for up to 48 nodes.

4:15 - 4:55 Prof. Peter Winkler, Department of Mathematics and Computer Science, Emory University

"Realization of Distance Matrices by Graphs"

Let $D = (d_{ij})$ be an $n \times n$ real symmetric matrix with zero diagonal and positive entries elsewhere, such that $d_{ij} + d_{jk} \leq d_{ik}$ for each i, j, k, i.e., the distance matrix of some metric space. A graph $G = <V,E>$ with edge-length function $f: E \rightarrow R^{+}$ is said to realize D if there are distinguished vertices v_1, lll, v_n in V such that $d_{ij} = d_G(v_i, v_j)$ for $1 \leq i, j \leq n$, where d_G is the ordinary path-length distance.

A realization is optimal if it has least possible total edge-length. We review past results and applications, address the question of the number of auxilliary vertices needed, and determine the computational complexity of finding an optimal realization.

7:30 Beer Party (Jordon Conference Room)

Friday, October 10th

8:15 - 8:40 Prof. A.Gyarfas, Hungarian Academy of Sciences

"Problems from the World Surrounding Perfect Graphs"

A family $\mathcal{G}$ of graphs is called χ-bound with binding f if $\chi(G') \leq f(\omega(G'))$ holds whenever G' is an induced subgraph of $G \in \mathcal{G}$. Here $\chi(G)$ and $\omega(G)$ denote the chromatic number and the clique-number of G. The family of perfect graphs appear in this setting as the family of χ-bound graphs with binding function $f(x) = x$. The talk is mainly devoted to open problems concerning χ-bound families of graphs.

9:00 - 9:40 Prof. Paul Stockmeyer, Department of Computer Science, College of William and Mary

"New Results in Coin Changing Algorithms"

The current American coinage system has the following desirable greedy property for every positive integer y, a minimum collection of coins adding up to y cents can always be obtained by repeatedly selecting the largest denomination coin not exceeding the remaining balance. However, if nickels were withdrawn from circulation, this property would be lost: the greedy selection method with $y = 30$ would choose a quarter and five pennies, while three dimes would form a smaller collection.

To date there is not a completely satisfactory method for determining which coinage sequences have this greedy property for all y, although several partial results are known. We present a variety of new results concerning when a non-greedy sequence can be augmented to form a greedy sequence of coin sizes. We also consider several properties that an ideal coinage sequence should satisfy and prove that they are mutually incompatible.

10:00 - 10:40 Prof. Peter J. Slater, Department of Mathematics and Statistics, University of Alabama at Huntsville
(Joint with D. W. Bange and A. E. Barkauskas)

"Disjoint Independent Dominating Sets in Graphs"

There is a lot of recent interest in the theory of linear algorithms for graph theoretic problems. In particular, much has been done to provide a general framework for algorithms to determine a minimum or maximum cardinality set S with a certain property (such as, S is a minimum dominating set) in a tree T. Here we introduce problems involving the determining of disjoint sets, each of which has the required property. Concentrating on various forms of dominating sets, we illustrate a similar general framework for algorithms to determine, when possible, a pair of disjoint sets in a tree, each with the specified property.

11:00 - 11:40 Prof. Carla Savage, Department of Computer Science, North Carolina State University

"Solving Problems on One-Dimensional Processor Arrays"

In this talk we present algorithms for solving combinatorial problem on one dimensional processor arrays in which data flows in only one direction through the array. We consider some simple problem such as sorting, evaluating expression, finding corrected components and spanning trees, as well as some more difficult problems such as ranking the elements in a chain of size n, rooting a spanning tree with n vertices, and computing the bi-connected components in a graph with n vertices. We show that each of these problems can be solved using arrays of size n in which the data enters at the first cell and flows through the array in only one direction until it leaves the last cell as output. We show also how the biconnectivity algorithm for the array yields a new sequential algorithm for computing bi-connected components.

1:20 - 2:00 Prof. Michael S. Jacobson, Chairman, Department of Mathematics University of Louisville

"Results on the Irregularity Strength of a Graph"

For the purpose of this presentation, a network is a graph in which each edge is assigned a positive integerweight. The degree of a vertex is the sum of the weights of the edges incident with it. A network is irregular if its vertices have distinct degrees, and the strength of a network is the largest weight assigned to any edge. For a graph G, the irregularity strength, s(G) is the minimum strength among irregular networks having G as an underlying graph.

Various results will be discussed including both upper and lower bounds for s(G) exact calculations for various "special" graphs and open problems. If time permits this parameter for r-uniform hypergraphs will be discussed.

2:20 - 3:00 Prof. Steve Locke, Department of Mathematics, Florida Atlantic University

"Long Cycles Generate the Cycle Space of a Graph"

What conditions need one place on a graph G to ensure that the cycles of length at least k generate the cycle space of G? Results due to Bondy and Lovász (connectivity), Hartman, Locke (connectivity and degrees), and Alspack, Locke and Witte (Cayley graphs) will be discussed.

An open question is also suggested relating this property to one on path lengths.

3:20 - 4:00 Prof. Dana Richards, Department of Computer Science, University of Virginia

"Rectilinear Steiner Tree Algorithms"

4:20 - 4:40 Prof. E. Ordman, Memphis State University

"Firing Squad Synchronization in Byzantine Graphs"

In the firing squad problem for graphs, a computer is located at each node of a graph and messages may be passed along edges. Computation is synchronous and proceeds by rounds. In the "firing squad" problem, it is required that initially disagreeing clocks all be reset, i.e., one fixed process should be able to initiate a process by which all the clocks are set to a common value in some future round. The map of the graph is unknown to the processes at the outset.

In the byzantine variation, we assume that some small number of processes (not exceeding a known number f, where the graph is known to have at least 3f + 1 nodes and be at least 2f + 1 -vertex connected) fail maliciously -- that is, they send false messages and change messages before forwarding them. We give an algorithm that allows clocks to be synchronized in this case. Since a faulty process could initialize the synchronization at any time, we also consider a variant where synchronization only occurs on a request from f + 1 processes.

The Second Clemson mini-Conference

ON[R]

Discrete Mathematics

Clemson, South Carolina
October 1-2, 1987

Schedule of talks
(All talks given in Student Senate Chamber)

Thursday, October 1st

1:10 - 1:20	Welcoming Remarks by Dr. Bobby Wixson, Dean of College of Sciences
1:20 - 2:00	Prof. C. L. Liu, Department of Computer Science, University of Illinois **"Generalization of Some Old Results in Combinatorics"** Generalization of some old results in combinatorics will be presented including the notion of balloting sequences of 0's and 1's, the definition of Latin squares, and a theorem due to Birkhoff and Von Neumann on doubly stochastic matrices.
2:20 - 3:00	Prof. Gary Chartrand, Department of Mathematics, Western Michigan University **"Variations On a Theorem of Petersen"** For an (r-2)-edge-connected graph G, it is shown that if the number of edge cutsets of cardinality r-2 and $\sum$ | deg v - r | are sufficiently bounded from above then G contains a matching of sufficiently large size. Several known results of this type are also discussed, especially Petersen's theorem.
3:20 - 4:00	Prof. L. W. Beineke, Department of Mathematics, Indiana University - Purdue University at Fort Wayne **"On Extreme Numbers of Subgraphs in Tournaments"** We consider tournament versions of this general graph problem: For a graph G and a family *F* of graphs, what is the greatest (or least) number of copies of G in any of the graphs in *F*? For ordinary tournaments, some of the interesting known results are when *F* contains the tournaments of order n and G is a cycle, a transitive tournament, or a strong tournament of some order m. We investigate corresponding problems for bipartite tournaments, where there are both interesting results and open problems.

4:20 - 5:00 Prof. Neil Robertson, Department of Mathematics
Ohio State University

"On Graph Minor Algorithms"

The work of Seymour and Robertson on graph minors bears on a number of algorithmic questions concerning finite graphs.

1. Does a graph G include another in some prescribed fashion?
2. Is a graph G included in some constructively defined structure?
3. Do graphs G with a specific structure have good algorithmic property?

Some special cases of these problems appropriate to the graph minor context have been solved by the development of polynomial-time algorithms. However, these solutions often have rather drastic practical drawbacks, and there are also many interesting questions left open. This lecture will try in an informal way to describe the main developments and to discuss what seem to be the natural open questions in this area.

8:00 p.m. Beer Party (Jordan Conference Room)

Friday, October 2nd

8:30 - 9:10 Prof. P. L. Hammer, Rutcor,
Rutgers University

"Bounds and Approximations of Pseudo-Boolean Functions"

Methods are presented for determining "best" majorization and "best" approximation of Pseudo-Boolean functions by linear ones. Applications are given to non-linear 0 - 1 approximations and to game theory.

9:30 - 10:10 Prof. E. J. Cockayne, Department of Mathematics,
University of Victoria

"Some Recent Results on Domination, Independence and Irredundance In Graphs"

This paper surveys some recent results concerning dominating, independent and irredundant sets in graphs obtained by C. Mynhardt, B. Bollobás, G. MacGillivray and the author. Several results of "Nordhaus-Gaddum type" i.e. $\xi(G)\xi(\bar{G}) \leq f(p)$ are discussed and also the concept of k-minimality of dominating sets is presented.

10:30 - 11:10 Prof. K. Brooks Reid, Department of Mathematics, Louisiana State University

"Majority Tournaments: Sincere and Sophisticated Voting Decisions under Amendment Procedure"

Suppose that each voter in a finite, nonempty set V of voters linearly orders, according to their preferences, a finite, nonempty set A of alternatives. For $a_1 \neq a_2$ in A, say that a_1 dominates a_2 if a majority of the voters rank a_1 above a_2 in their individual linear orders. If no ties are allowed (e.g. |V| is odd), there results a tournament, called a majority tournament, with vertex set A and domination as above. Under amendment procedure, a majority tournament and some voting order, say $a_1, a_2, \ldots, a_m$, of the m alternatives in A are given. In the first vote a_1 and a_2 are paired for majority vote, the defeated alternative being eliminated; at the i th vote, $2 \leq i \leq m - 1$, the alternative surviving the (i - 1) th vote is paired with a_{i+1} for a majority vote, the defeated alternative being eliminated. The sincere voting decision is the alternative surviving the final (i.e. (m - 1) th) vote. The sophisticated voting decision is obtained by first anticipating the decisions of all possible final votes, then recursively anticipating the decisions of earlier votes based on anticipated decisions of later votes until the anticipated decision at the first vote, the sophisticated voting decision, is identified. This talk concerns the location of and the relationship between the sincere and sophisticated decisions in the majority tournament and in the voting order. It is an expansion and extension of work by N. R. Miller (American Journal of Political Science, XXI, 4, November 1977, pp. 769-803).

11:30 - 12:10 Dr. F. R. McMorris, Office of Naval Research

"Tolerance Intersection Graphs"

The intersection graph of a family of sets is the graph whose vertices are the sets, and an edge is between two vertices if the two sets have a nonempty intersection. When restrictions on the types of sets are made (e.g., intervals of the real line, arcs of a circle, subtrees of a tree), it is possible to establish nice theorems having applications ranging from genetics to scheduling problems. Tolerance intersection graphs require the "strength" of the intersection of two sets to be above a certain "tolerance" before an edge is established. The study of such graphs is in its infancy and was initiated by Golumbic, Monma, and Trotter in 1982. In this talk I will survey some known results, outline a general research plan, and present some new preliminary results.

2:00 - 2:40 Prof. Ron Gould, Department of Mathematics, Emory University

"Neighborhood Unions and Extremal Graph Problems"

For a graph G of order n and a set $S \subseteq V(G)$, the *neighborhood of S* is defined to be

$$N(S) = \{u \mid us \in E(G) \text{ for some } s \in S\}.$$

The set $N(S)$ is merely the union of the neighborhoods of the individual vertices in S and the value $|N(S)|$ can be thought of as the degree of the set S. We consider a variety of results obtained by bounding $|N(S)| \geq k(n)$, where k depends on the order of the graph G. The typical form for such a result is:

Given a graph G of order n and a property P_1, if $|N(S)| \geq k(n)$ for all subsets $S \subseteq P(G)$ satisfying P_1, then G has property P_2.

Included will be hamiltonian and highly hamiltonian type results as well as results about matchings, extremal path and cycle lengths, and Turan type extremal results. An analog of the Bondy-Chvátal degree closure will also be considered.

3:00 - 3:40 Dr. C. L. Monma, Bell Communications Research

"Optimally Embedding Planar Graphs"

It is well known that a planar graph can be embedded in linear time. However, a planar graph may admit many possible embeddings, some of which are "better" than others. We consider a general class of problems involving "optimally" embedding planar graphs. We introduce several measures for evaluating an embedding and examine the computational complexity of minimizing each of them. These measures are motivated both by applications which require "nice" embeddings, and by algorithms which work well only given a "nice" embedding. This talk surveys recent results on joint work with Dan Bienstock.

4:00 - 4:40 Prof. M. Fellows, Department of Computer Science, University of Idaho

"Robertson-Seymour Posets: Applications of the Immersion Order"

The well partial ordering of finite graphs under the immersion order has a variety of striking applications to problems of VLSI layout and channel routing and to problems of network integrity. These new applications and current research directions aimed at developing practical algorithms based on the fundamental work of Robertson and Seymour will be presented.

The Third Clemson mini-Conference

ON[R]

Discrete Mathematics

Clemson, South Carolina
October 6-7, 1988

Schedule of talks
(All talks given in Jordan Auditorium, G-33)

Thursday, October 6th

1:30 - 1:40 Welcoming Remarks by Dr. Bobby Wixson,
Dean of College of Sciences

1:40 - 2:20 Prof. Herbert S. Wilf, Department of Mathematics,
University of Pennsylvania

"A Choice Generating Function Specimen"

This talk will be about joint work of Andrew Odlyzko and myself. It concerns a problem in arrangements of coins, and the remarkable generating function that results from considering that problem. The asymptotics of the number of solutions will also be given.

2:40 - 3:20 Professor Peter L. Hammer, Department of Mathematics & Computer Science
Rutgers University

"Boolean Functions and Graph Theory"

The presentation will survey various interactions between graph theory and Boolean functions pointing out in particular some algorithms based on this relationship.

3:40 - 4:20 Professor Derek Cornell, Department of Computer Science
University of Toronto

"Independent Set Bonding of Perfect Graphs"

One of the earliest results in perfect graph theory is: given two perfect graphs each containing a clique of size K, the graph formed by bonding these two graphs on these cliques is also perfect. Later it was shown that bonding on specific sub-graphs is guaranteed to preserve perfectness only if the sub-graphs are cliques. In this talk we discuss the problem of bonding on independent sets and state conditions in which this bonding preserves perfectness. As a by-product we have a new composition operation for building perfect graphs. This is joint work with Jean Fonlupt.

Friday, October 7th

8:30 - 9:10 Professor V. Rödl, Department of Mathematics
Emory University

(To be determined)

9:30 - 10:10 Professor W. T. Trotter, Department of Mathematics & Computer Science
Arizona State University

"The Order Dimension of Convex Polytopes and Planar Maps"

With a convex polytope M in R^3, we associate a partially ordered set P_M whose elements are the vertices, edges, and faces of M ordered by inclusion. It is well known that the order dimension of P_M is at least 4, and W. Schnyder has shown that it is exactly 4 when every face of M is a triangle. In this paper, we show that the order dimension of P_M is at most 6 for every convex polytope in R^3. In fact, the same bound applies whenever P is the partially ordered set of vertices, edges and faces of a planar map. Our proof relies heavily on the techniques developed by Schnyder to prove that a graph G is planar if and only if the order dimension of the partially ordered set determined by its vertices and edges is at most three.

10:30 - 11:10 Professor Michael D. Plummer, Department of Mathematics
Vanderbilt University

"The Theory of Euler Contributions: Some New Applications"

All first year graph theory students learn about the classical Euler formula relating the number of points, lines and faces of a graph embedded in an orientable surface. One particularly well-known corollary of this result tells us that planar graphs must have points of small degree. But it is not so well-known that long after Euler's time, Lebesgue and Ore were able to "fine-tune" the Euler formula to get interesting results concerning the facial configurations surrounding such points of low degree. In this talk, a brief outline of some of these results will be presented which we hope will prove useful to those who study properties of graphs embedded in surfaces. Some quite recent results obtained by the author and others which employ the theory of Euler contributions will then be discussed. These results arise in three different areas of graph theory: (1) matching, (2) cyclic coloration and (3) pancyclicity.

11:30 - 12:10 Professor Allen J. Schwenk, Department of Mathematics & Statistics
Western Michigan University

"The Ultimate Subsequence Counting Algorithm"

1:40 - 2:20 Professor Gary Parker, School of Industrial & Systems Engineering
Georgia Institute of Technology

"On Recursively Constructed Graph Families"

Much attention has been given recently to graph classes which are recursively definable among which are series-parallel graphs, Halin graphs, and partial k-trees. In particular, it is well known that many otherwise hard problems are solvable on these sorts of graphs using dynamic programming. As a consequence, interest has shifted somewhat to now focus on certain limits to this strategy as well as the development of a formal model of computation applicable to any recursive graph family. In this talk, we examine available results.

2:40 - 3:20 Professor Arthur T. White, Department of Mathematics & Statistics
Western Michigan University

"Graph Imbeddings"

Three basic techniques for imbedding graphs on surfaces are reviewed; these are: (1) rotation schemes, (2) voltage graphs, and (3) surgery. Technique (2) is readily applied, for example, to obtain genus imbeddings, and related combinatorial structures, for k(n, n, n). All three techniques are illustrated, for the quadrilateral tessellation of the torus by the cartesian product $C_4 \times C_4$. This imbedding is extended, via (3), to a genus imbedding for $C_4 \times C_4 \times C_4$. Neither (3) nor (2) seems appropriate for $C_3 \times C_3 \times C_3$, but (1) suffices. The general problem of minimal imbeddings of repeated cartesian products of cycles is discussed. Exact and asymptotic results are presented. There is relevance to the genus parameter for finite abelian groups. (Some of the work reported is joint with Tomaz Pisanski and Bojan Mohar.)

3:40 - 4:20 Professor Terry McKee, Department of Mathematics & Statistics,
Wright State University

"Upper Bound Multigraphs For Posets"

By allowing multiple edges to represent multiple intersection, much of the theory and many of the applications of intersection graphs can be upgraded to intersection multigraphs. In particular, upper bound multigraphs (i.e., intersection multigraphs of all 'upsets' of elements) can be characterized and shown to determine their associated posets up to isomorphism. This also produces a characterization of those posets which have chordal or interval upper bound multigraphs.

4:40 - 5:20 Ewa Kubicka, Department of Mathematics & Statistics,
Western Michigan University

"An Introduction to Chromatic Sums"

We introduce the new concept of the chromatic sum of a graph G, the smallest possible total among all proper colorings of G using natural numbers. We show that computing the chromatic sum for arbitrary graphs is an NP-complete problem. Indeed, a polynomial algorithm for the chromatic sum would be easily modified to compute the chromatic number. Even for trees the chromatic sum is far from trivial. We construct a family of trees to demonstrate that for each k, some trees need k colors to achieve the minimum sum. In fact, we prove that our family gives the smallest trees with this property. Moreover, we show that asymptotically, for each value of k, almost all trees require more than k colors. Finally, we present a

linear algorithm for computing the chromatic sum of an arbitrary tree.

The Fourth Clemson mini-Conference

ON[R]

Discrete Mathematics

Clemson, South Carolina
September 28-29, 1989

Schedule of talks
(All talks given in Student Senate Chambers)

Thursday, September 28

1:00 - 1:10 Welcoming Remarks by Dr. Bobby Wixson,
Dean of College of Sciences

1:10 - 1:50 Prof. Frank Harary, Dept. of Computer Science
New Mexico State Univ.

"Sum Graphs - Survey

The sum graph of a set S of positive integers has node set S, with two nodes adjacent if and only if their sum is in S. We have shown that every graph can be made into a sum graph by adding isolated nodes. The smallest such number is the sum number, σ (G). In our original paper, we stated as a "True Conjecture" that every tree T has $\sigma(T) = 1$; recently proved by Ellingham. With Bergstrand and four of her students, we proved that the sum number of the complete graph is $\sigma(K_n) = 2n - 3$. Many open questions abound especially in extending the concept to some digraphs of non-abelian groups, and to the sum number of finite abelian groups.

2:05 - 2:45 Prof. Trevor Evans, Dept. of Math. & Computer Science
Emory University

"Algebraic Aspects of Combinatorics"

We survey some recent applications of algebra to combinatorics where the algebraic tools involved are not the familiar permutation groups, finite fields, vector spaces, etc. but more exotic algebraic structures. Applications to orthogonal Latin squares, designs and graphs are discussed.

3:10- 3:40 Prof. Daniel Kleitman, Mathematics Dept.
MIT

"On Zero-Trees"

Consider an integer valued function on the edge-set of the complete graph K_{m+1}. The weight of an edge-subset is defined to be the sum of the associated weights. It is proved, that there exists a spanning tree with weight 0 modulo m.

3:55 - 4:35 Prof. Irvin Hentzel, Dept. of Mathematics
Iowa State University

"The Characteristic Function: An Alternative To Counterexamples"

The concept of a characteristic function is to make it easy to demonstrate that something is not true. For example, to prove that a matrix is not invertible, one only needs to show that its determinant is zero. To prove that two trigonometric expressions are not equal, one need only find a number on which they evaluate differently.

In non-associative algebras we are continually asked if identities $p_1, p_2, \ldots p_k$, will imply identity q. We are asking, "In the free non-associative algebra, is the identity q in the T-ideal generated by $p_1, p_2, \ldots p_k$, ?" Here the characteristic function wil be a function which maps the T-ideal to zero, but maps q to something nonzero.

The contstruction of such characteristic functions can be done through traditional representation theory using Young's tableaus. For algebras over a field the process is complete in that q is not in the T-ideal if and only if there is a characteristic function which proves it. Since this process can use the tableaus, it is more transparent than purely computed characteristic functions.

One hopes to produce a characteristic function which so clearly expresses the process of the identities that is easily seen that it maps elements of the T-ideal to zero. But even when it can not be so easily seen, verifying the characteristic function is magnitudes of order less work than verifying that an algebra satisfies a set of identities.

4:40 - 5:20 Dr. Paul Seymour, Bellcore

"Separators In Non-Planar Graphs"

7:30 Social, Jordan Room

Friday, September 29

8:00 Coffee and Doughnuts, Student Senate Chambers

8:20 - 9:00 Prof. J. S. Provan, Curriculum in ORSA,
Univ. of North Carolina

"Approximating Two-Terminal Reliability in Graphs"

A survey is given of polynomial time schemes for bounding the probability - in a graph with random arc failures - that two specified vertices are connected by a path of operating edges. Two special Schemes will be highlighted: The first uses the powerful property of Shellability inherited by portions of the Underlying System, and the second uses a new algorithm for the reduction of a two-terminal planar graph by means of Series - parallel and delta-wye-delta transformation.

9:15 - 9:55 Prof. Charles J. Colbourn, Dept. of Combinatorics and Optimization,
University of Waterloo

"Leaves and Neighbourhoods of Triple Systems"

We explore two graph-theoretical questions which arise in combinatorial design theory. First, we examine the structure of graphs which are leaves (missing edge graphs) of partial triple systems. We then use these results to ask which multigraphs can be neighbourhoods (pairs appearing with a fixed element) in a triple system. The talk emphasizes connections between graph theory and design theory.

2:05 - 2:45 Prof. Jerrold R. Griggs, Mathematics Department
University of South Carolina

"Representations of Uniform Hypergraphs Over $GF(2)$"

Let B be a family of t-subsets of $[n] = \{1, \ldots, n\}$ which we view as the edge set for a t-uniform hypergraph. We say a *representation of* B *over GF(2)* is a $t \times n$ (0,1)- matrix M such that every set of columns of M indexed by a member of B is linearly independent over $GF(2)$. This concept is motivated by a problem in extremal set theory" Chung, Frankl, Graham, and Shearer and Faudree, Schelp, and Sós study families B with the property that the maximum size of a family $F \subseteq 2^{[n]}$, such that the intersection of any two sets in F contains some set in B, is just 2^{n-t}. They conjecture in particular that B has this property when it consists of all cyclic translates of some t-subset X. Griggs and Walker observe that B has this property (and much more) whenever it has a representation as defined above. They show that a representation exists for the (smaller) collection of all ordinary translates of a t-subset of X. They conjecture more generally that every hypergraph B of maximum degree t has a representation, which is easily verified for $t = 1, 2$. The more challenging case $t = 3$ has been proven by Füredi, Griggs, Holzman, and Kleitman by finding a suitable vertex-coloring of the 3-uniform hypergraph.

3:00 - 3:40 Prof. Siemion Fajtlowicz, Dept. of Mathematics
University of Houston

"On Conjectures and Methods of Graffiti"

Graffiti is a computer program making graph-theoretical conjectures. I will discuss in this talk some of the solved and some of the open conjectures of the program.

In the past, the trivially true conjectures, were the greatest obstacle in improvement of the performance of Graffiti. I will describe the current methods which I use to handle this problem, as well as some new activities of Graffiti like concept formation. I will also review and attempt to formulate mathematically certain questions related to the problem of automated discovery.

3:55 - 4:25 Prof. Gerd Fricke, Dept. of Mathematics
Wright State University

"Strong Matchings on Trees"

We show that for a tree T, $2\beta^* = \text{VIR}$, where β^* is the maximum number of independent K_2's and VIR is the maximum cardinality of a very open irredundant set. We also give a linear time algorithm for computing VIR (T).

4:30 - 5:00 Prof. Robin Thomas, Dept. of Mathematics
Georgia Tech.

"How Many Cops Are Needed to Catch a Robber?"

We consider a version of a "cops-and-robber" game in a finite graph and show its relation to tree-width. Then we generalize the game to infinite graphs and show how it relates to excluded minor theorems. For instance, for an (infinite) graph G the following conditions are equivalent:

(i) G has no minor isomorphic to the infinite $\aleph_1$ - branching tree,
(ii) countably many cops win the game in G,
(iii) G has a "tree-decomposition" into at most countable pieces such that the underlying tree has no infinite path.

This is a joint work with Neil Robertson and P. D. Seymour.

10:10 - 10:50 Prof. George L. Nemhauser, ISYE
Georgia Institute of Technology

"Solving Combinatorial Optimization Problems By Constraint Generation Algorithms and an Application to Graph Coloring"

Many combinatorial optimization problems can be formulated as linear programs with an exponential number of constraints. We discuss contraint generation algorithms for solving such problems and their relationships to complexity and compact formulations. We then apply the results to the edge coloring problem.

11:205- 11:45 Prof. Linda M. Lesniak, Dept. of Math. & Computer Science
Drew University

"Tolerance Intersection Graphs"

In [Congressus Numerantium 35 (1982), 321-331], Golumbic and Monma introduced the concept of tolerance graphs. A graph G = V, E) is called a tolerance graph if there exists a collection $\{I_x \mid x \in V\}$ of closed intervals on a line and a set $\{t_x \mid x \in V\}$ of positive numbers satisfying $x\,y \in E \Leftrightarrow |I_x \cap I_y| \geq \min\{t_x, t_y\}$ where $|I|$ denotes the length of interval I. They showed that if $t_x = c$ for every $x \in V$ and some constant c, then we obtain exactly the class of interval graphs. Thus tolerance graphs indeed generalize interval graphs. A more general approach was taken by Jacobson, McMorris and Mulder (preprint). Let Z be a set and let Z be a measure on Z assigning to each non-empty subset S of Z a positive real number $\mu(S)$. Let $\mathcal{S} = \{S_v\}_{v \in V}$ be a (finite) collection of non-empty subsets of Z, and let $t: \mathcal{S} \to R^+$ be a mapping which assigns to each subset S_v a tolerance t_v. Finally, let $\phi: R^+ \times R^+ \to R^+$ be a function assigning a positive real number to each pair of positive reals. Then the tolerance intersection graph of $(\mathcal{S}, \mu)$ and (t, ϕ) is the graph G = (V, E) with vertex set V and
$x\,y \in E \Leftrightarrow \mu(S_x \cap S_y) \geq \phi(t_\mu, t_y)$

Clearly, the concept of tolerance intersection graphs generalizes tolerance graphs, where $\mathcal{S}$ is a collection of intervals on a line, $\mu(S) = |S|$ for each $S \in \mathcal{S}$, and $\phi(t_x, t_y) = \min\{t_x, t_y\}$.

A survey of recent results involving tolerance intersection graphs will be given.

1:10 - 1:50 Prof. Dan Bienstock, Dept. of Indust. Eng. & Op. Research
Columbia University

"Recent developments on Path-Width, Tree-Width and Graph Searching"

We will describe some results due to (in various combinations) the author, Neil Robertson, Paul Seymour and Robin Thomas, that show an important connection between path-width and tree-width on the one hand, and graph searching on the other. The problem of capturing a fugitive in a graph, using fewest possible searchers, was originally of interest in computer science because of its formal resemblance to certain pebbling games.. The graph invariants path-width and tree-width arose naturally in the proof of Wagner's conjecture due to Robertson and Seymour. As we will show, for each of these two parameters there is a min-max characterization, which shows that it is equal to the graph-searching number in an appropriately defined searching game. This yields (1) A very short proof of LaPaugh's theorem, that a graph can be searched with fewest guards in a monotone way, and (2) A theorem stating that if a graph *G* does not contain a forest *F* as a minor, then the path-width of *G* is less than $|V(F)| - 1$.